CONSTRUCTION PROCEDURES
In Two Demonstration Houses

DESIGN, CONSTRUCTION AND COST DATA ON TWO HOUSES BUILT UNDER RESEARCH CONTRACT WITH HOUSING AND HOME FINANCE AGENCY

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ISSUED BY **THE SMALL HOMES COUNCIL**

UNIVERSITY OF ILLINOIS · URBANA, ILLINOIS

CONSTRUCTION PROCEDURES
IN TWO DEMONSTRATION HOUSES

By

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TABLE OF CONTENTS

INTRODUCTION

Few builders have had the opportunity to investigate and prove to their satisfaction that recently developed techniques can save time and materials in small home construction. To demonstrate that quick and easy savings can be made, a research contract was executed between the University of Illinois and the Housing and Home Finance Agency. Under this contract, the Small Homes Council developed evidence showing that dwellings which meet this country's high standard for family living can be produced under today's conditions of home financing and construction. This evidence is in the form of material and labor cost-data for two demonstration houses built in Champaign, Illinois, in the summer of 1952. The houses were privately financed and were sold on completion.

The two houses were identical in plan, being one-story, basementless houses of approximately 1,000 square feet. They were designed to be typical of the small house being built today. The second house served as a check on the first and gave an opportunity to improve on the techniques used in the first house.

The techniques used are described in detail in this report* since they can cut costs for any builder regardless of the size of his operation.

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* This report is a condensation of "A Demonstration of New Techniques for Low-Cost Small House Construction" by R. H. Harrell and J. T. Lendrum, University of Illinois, Small Homes Council, Nov. 1952, submitted pursuant to a contract with the Office of the Administrator, Housing and Home Finance Agency, authorized under Title III of the Housing Act of 1948, as amended.

DESIGN OF DEMONSTRATION HOUSE

In planning the demonstration house, a program was written which called for a three-bedroom house having approximately 1,000 sq. ft. of floor area. The resulting structure was 30' x 34' (inside dimension) and contained besides the three bedrooms, a laundry-bathroom, a large kitchen with adequate space for eating, and a flexible living room which could be, by the use of less than ceiling-height storage closets, divided into a living room and a play area.

It was felt that this plan met the program requirements in that it provided for the following:

- Activity Areas. Space for all activities required by families was included in the house; namely, 1) the bedrooms which are primarily sleeping areas, 2) the kitchen area which is a work and eating space, and 3) the living room which provides both play area for general activities for either children or adults, and a living area.

- Open Planning. The basic principle of open planning is that each space borrows either actually or visually from adjacent areas. In the house plan shown, the kitchen borrows space from the entrance and hallway through the use of a large opening between the spaces and through the omission of a door. The ceiling area painted the same color throughout the entire space carries through and ties one area into the other. The living and activity (or play) areas are even more closely related. The use of a storage wall 6'-4" high allows the eye to go beyond the limits of the room and borrows space from the adjacent room; at the same time, the height of the storage wall gives complete privacy for those in the bedroom area.

- Multi-Purpose Rooms or Areas. These are closely related to open planning and are designed to make the fullest use of all available floor area. An example is the play area that can be either thrown into the living room or into the play space. (See pages 6 and 7.)

- Solar Orientation. The house is of such a design that it can be arranged on any lot so that the major glass area of the living room is facing south. By such placement, the heating burden can be reduced in the winter, and at the same time a general feeling of well-being can be obtained from the light received by the house. Moreover, through the use of the overhangs, the rays of the sun can be excluded from the living portion of the house during the summer months. The wide overhang required to provide this control can be easily constructed by an extension of the roof plane.

- Adequate Circulation. Hall space is often considered to be waste space, but many home planners overlook the fact that a hall space does not need to be defined by walls. If a house is planned so an entrance door into a living room makes it necessary for traffic to pass diagonally across the room, the designer has produced a hallway across that room just as definitely as though it were limited by walls. In the plan as finally designed, there is not only a minimum of hall space, but entrances or rooms are so located that traffic need not pass through or across the living portion of another room in order to secure access to another part of the house. This increases the usefulness of the living areas without increasing their size.

. Storage. Provision for adequate storage for the family belongings is a necessary adjunct to any successful house plan, but particularly to those plans that provide neither a basement or an attic as storage areas. In the demonstration house plan, an arbitrary 4-foot closet space was chosen for each individual (the house assumed a maximum occupancy of five people). In addition, storage space was provided in the following locations:

1. Linen closets in the bathroom.

2. Above and below the work counters and also along one entire wall of the kitchen.

3. A storage wall between the living area and the corridor (or play space).

. The Laundry-Bathroom. In addition to the standard items that are considered essential in planning a small house, the location of the laundry was carefully studied. Three general choices exist in a basementless one-story house--laundry equipment may be in the kitchen, it may be in a separate work area, or it may be combined with the other plumbing fixtures in the bathroom. The latter location was chosen for the demonstration house on the basis of the following decisions:

1. Laundry operations are not compatible with the preparation of food and eating.

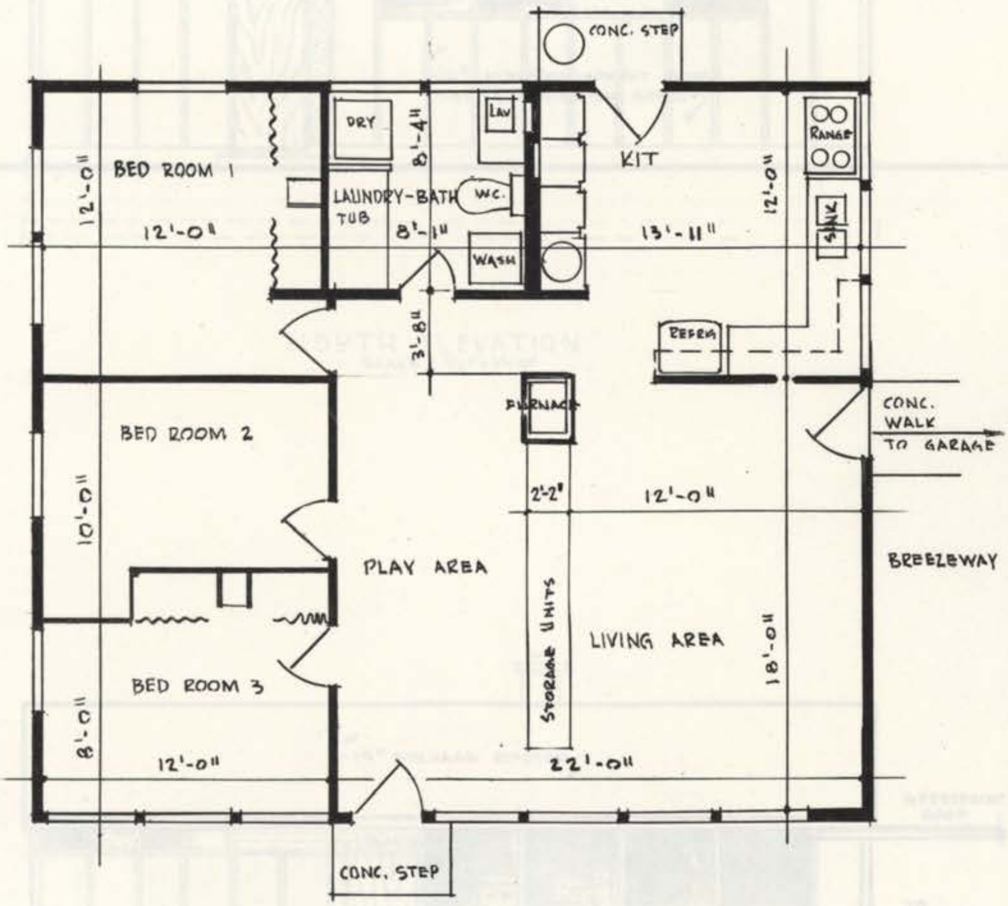
2. The house being small in area, it was not desirable to provide a separate utility room to house the water heater, the furnace, and the laundry equipment.

3. Water supplies would be available in the bathroom so that no additional plumbing costs would be involved. Also, the walls of the bathroom were to be treated with materials which make them impervious to water or to moisture which is frequently developed in laundering.

4. Most of the articles to be laundered come from the bedrooms, either in the form of bedding or personal linen.

5. The bathroom, of all of the rooms of the house, is the one which is least likely to be upset by laundering during the normal hours for that operation.

In addition to the flexibility obtained from placement on the lot, the basic structure of the house is so designed that many variations in room arrangements are possible. It can, for example, be made into a two-bedroom house, a two-bedroom house with a dining-room alcove, into a variety of houses with two large bedrooms and a separate dining and play area, a two-bedroom house with an extremely open plan, and several variations on the three-bedroom plan.



FLOOR PLAN

SCALE: 1/8" = 1'-0"

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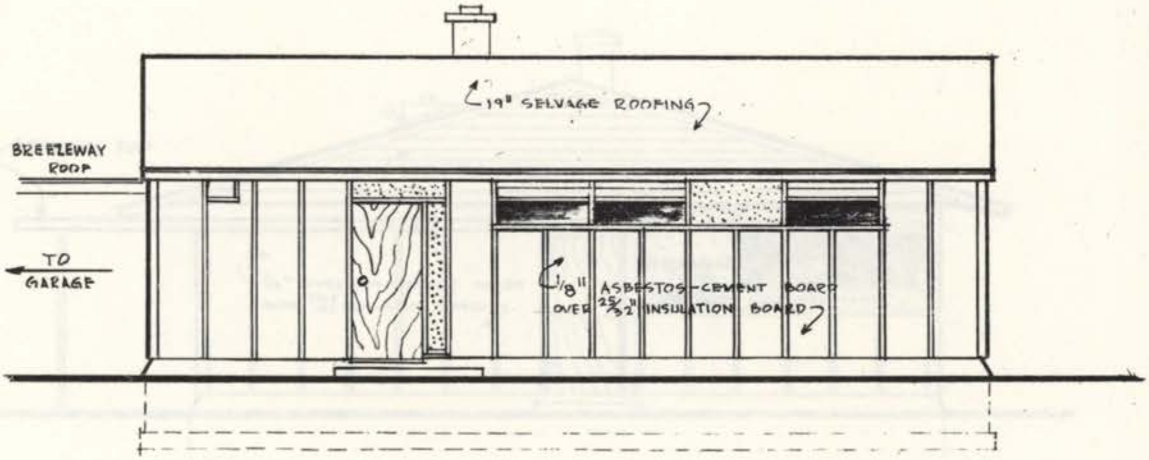
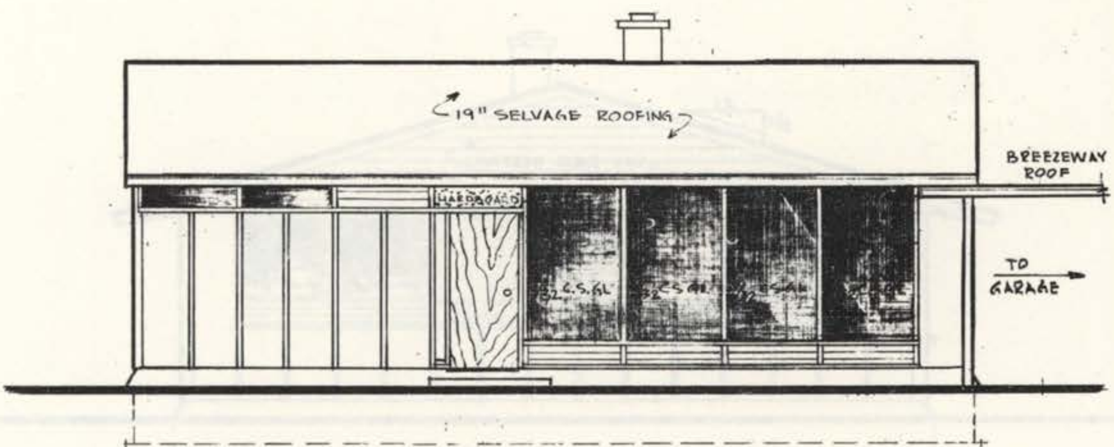


NORTH ELEVATION
SCALE: 1/8" = 1'-0"



SOUTH ELEVATION
SCALE: 1/8" = 1'-0"

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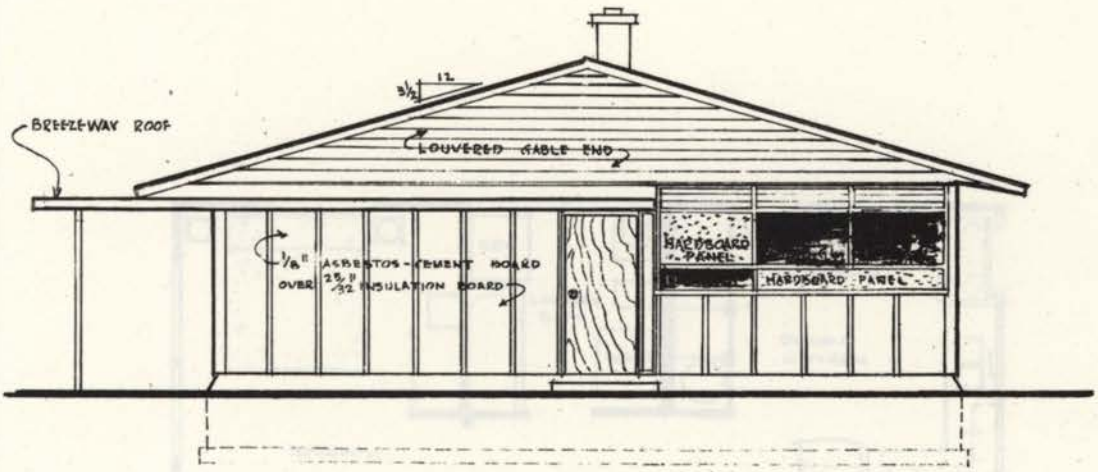
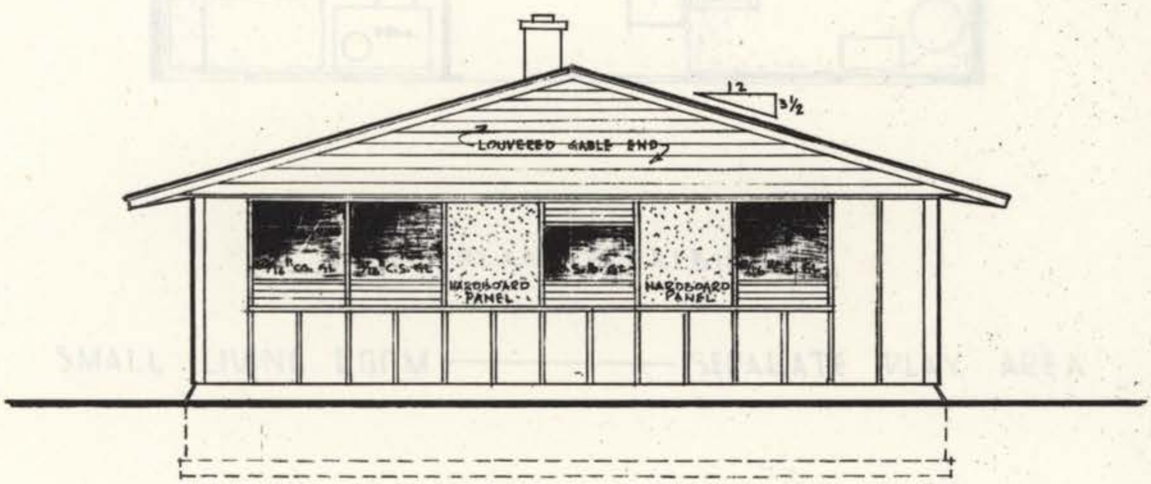


EAST ELEVATION
SCALE: 1/8" = 1'-0"



WEST ELEVATION
SCALE: 1/8" = 1'-0"

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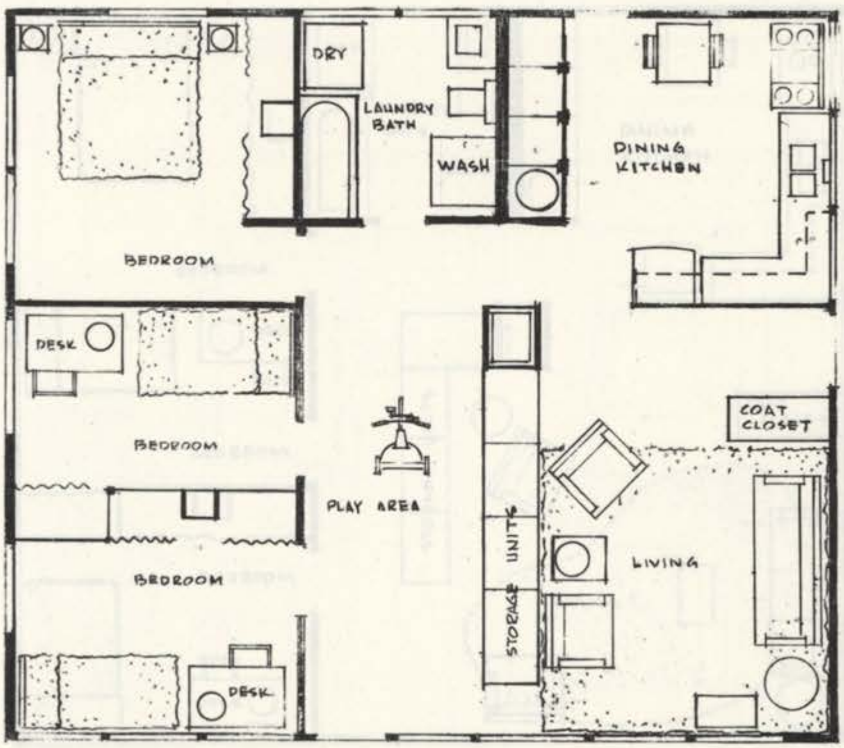
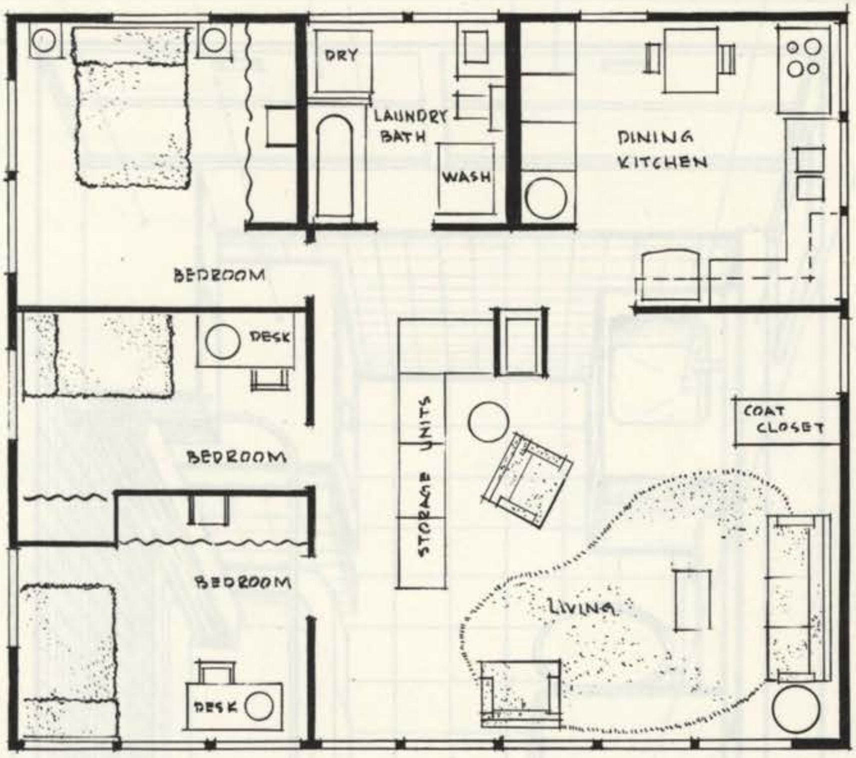


PLAN FLEXIBILITY

SMALL LIVING ROOM —————— SEPARATE PLAY AREA



PLAN FLEXIBILITY

LARGE LIVING ROOM

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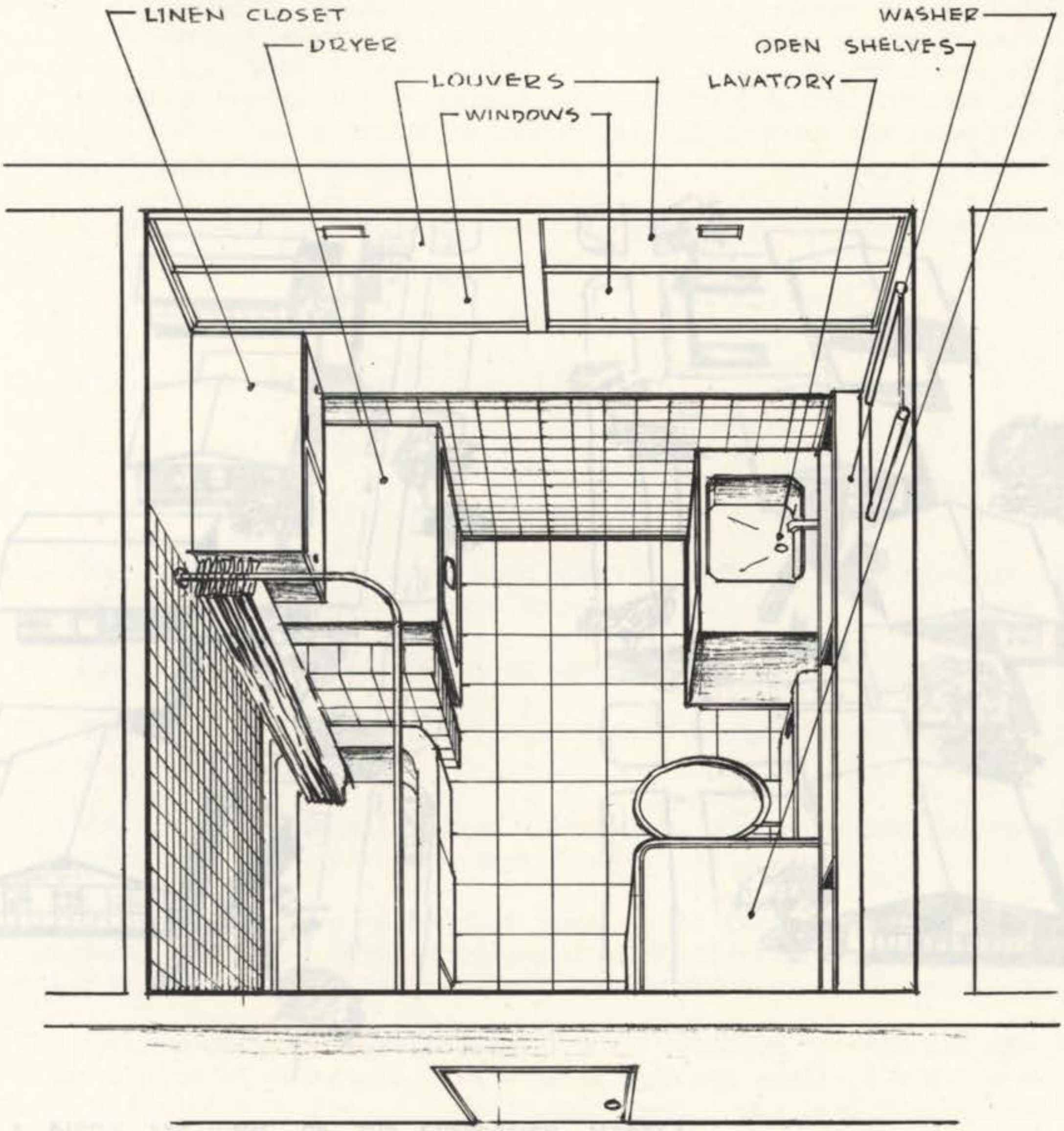

LAUNDRY—BATH
PERSPECTIVE SKETCH

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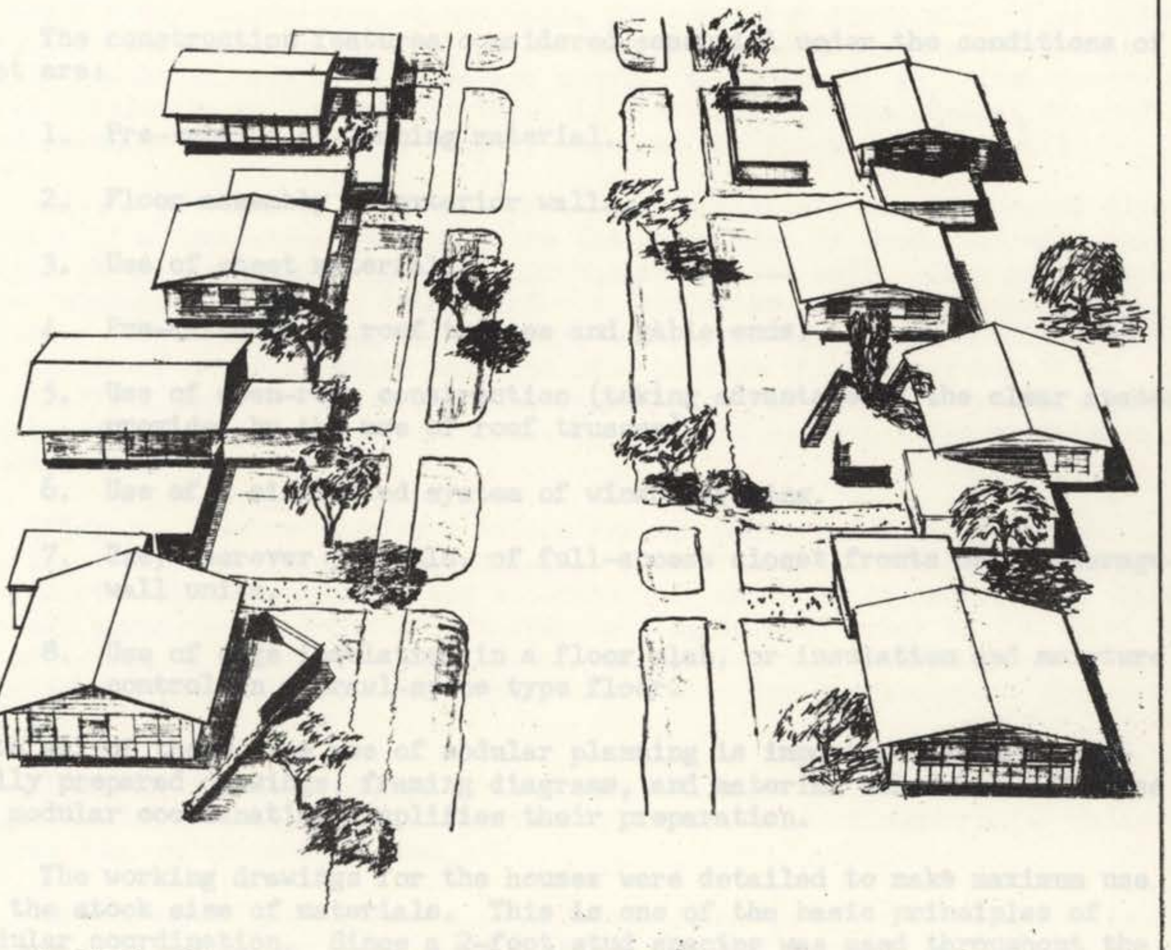

A BIRD'S-EYE VIEW OF THE SUBDIVISION MODEL:

NOTE THE PLACEMENT OF GARAGES, CARPORTS, FENCES AND THE ORIENTATION OF THE HOUSES ON THE LOTS. EXTERIOR VARIATIONS ARE POSSIBLE BY THESE MEANS. DIFFERENT SCHEMES ARE SHOWN AS USED ON ONE STREET.

CONSTRUCTION FEATURES

The construction features used in the demonstration houses are applicable to practically any one-story frame house. Some of these construction features may, in addition, be adapted with virtually no change to split-level houses, to two-story houses, to masonry houses, and to a lesser extent, to row houses. In addition to describing the general procedures involved in each of the major construction techniques, this report outlines the steps which must be taken in order to include these features in the construction of a house of different designs.

The construction features considered essential under the conditions of test are:

1. Pre-cutting of framing material.
2. Floor assembly of exterior walls.
3. Use of sheet materials.
4. Pre-assembly of roof trusses and gable ends.
5. Use of open-room construction (taking advantage of the clear spaces provided by the use of roof trusses).
6. Use of a simplified system of window framing.
7. Use, wherever possible, of full-access closet fronts or of storage-wall units.
8. Use of edge insulation in a floor slab, or insulation and moisture control in a crawl-space type floor.

With all of these, the use of modular planning is important, as are carefully prepared drawings, framing diagrams, and material schedules. The use of modular coordination simplifies their preparation.

The working drawings for the houses were detailed to make maximum use of the stock size of materials. This is one of the basic principles of modular coordination. Since a 2-foot stud spacing was used throughout the building, the planning module was 2'-0". (This is a multiple of the basic 4-inch module of all dimensional coordination, and again is a half of a 4-foot module which is one of the most common standard dimensions of sheet material.) To eliminate the cutting of interior materials, the full 2-foot module was taken to the inside face of the exterior wall; thus, the 30' x 34' dimension of the building is the inside dimension while the exterior nominal dimension is 30'-8" x 34'-8".

JOB ORGANIZATION

Step 1: The first step in organizing a construction project is to adjust the dimensions of the building so they are suitable for the use of modular materials. If possible, the interior dimensions should be in even feet or multiples of 16 inches if that is the stud spacing being used. In any case, they should be in multiples of 4 inches.

Step 2: To secure a successful, organized job, the foundation wall details should be adjusted to include edge insulation and proper heating systems. If a foundation wall of concrete block is used, the dimensions previously chosen for the inside face of the walls for the first floor will be satisfactory. No cut block in the foundation wall should be necessary. The basic 4-inch module is half of the average nominal thickness of an 8-inch concrete block foundation wall which, in turn, is a multiple of the 16-inch or 2'-0" stud spacing. (See drawings, page 15, for the cap block detail used.)

Edge insulation is essential for a successful warm and dry basementless floor. If a foundation carried below the frost line is used, the edge insulation should go between the slab and the foundation wall. On a grade-beam type foundation it can go outside of the foundation wall if adequately protected.* If it is a crawl-space floor, the insulation should be attached to the inside of the foundation wall and also between the ends of the floor joists.** A heating system which provides heat near the outside walls of the house, or in the floor, or in the ceiling, is essential for comfort in a basementless house.

Step 3: Prepare framing drawings for all walls and partitions, showing the exact size and location of members. From this, make a cutting schedule of all pieces, and summarize the schedule in a material or order list. Precut all parts to the schedule. A framing diagram made prior to the start of construction is a necessity; a foreman on a job is not in a position to make a satisfactory wall layout while he is directing the operations of the workmen.

From the framing diagram it is a simple matter to make a material list, which can be used either to order the number and size of members for delivery to the job, or to pre-cut them.

With a house plan adjusted so the wall dimensions are an even multiple of the stud space, the wall studs required for the exterior walls can be laid out, as well as the other framing members, headers, jack studs, cripples, blocks, plates, etc. (See drawing, page 17.) These should be counted and scheduled so that the number of units of each size required is listed in the cutting schedule. (See schedule, page 36.) For maximum efficiency, modular windows must fit into the wall with a minimum of additional framing material or of movement of wall framing members. Often, however, the slight movement of a window on the wall of a room will make it possible to eliminate several

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* Small Homes Council Circular F4.3, "Concrete Floors for Basementless Houses".

** HHFA Technical Bulletin No. 1, November 1947.

extra framing members and will not affect the placement of furniture or the use of the room. The ideal coordination between windows and walls was achieved in the demonstration house project, but it is impossible to arrive at this unless extreme care is taken with every step and unless the window system used is completely coordinated with the wall framing system.

The framing drawing should be given to the carpenter foreman, and he should be instructed to follow that drawing and cautioned not to change the framing system on the job. He should be provided with the material called for in the framing drawing and material schedule.

Use power equipment to pre-cut all pieces. The exact type of equipment and the extent to which jigs and fixtures are used will depend on the number of pieces to be cut.

Step 4: Pre-assemble all exterior walls in a horizontal position, including the application of exterior siding material and trim.

Floor assembly of wall panels is an essential part of the successful organization of any house construction job. The most difficult operation here is the control of the workmen who, without exception, want to tip the wall into position much too soon. As a matter of discipline, the foreman should be instructed not to tip the wall into position until all of the operations are complete. It is much easier to carry on each of the assembly operations when the wall is in a horizontal position. A wall 36 feet long, which is complete with window frames, exterior finish material, and trim, can be handled easily by five men.

Assembly proceeds as in a normal job. There is no difference. Following the framing diagram exactly, the framing members are assembled and the sheathing, louver frames, and exterior siding are applied. The use of sheet material obviously simplifies construction at this point as it does in many other later points in the house assembly. Care must be taken, of course, to insure accuracy in each of these steps so that no cutting and fitting are required. Corrections must be made so that the wall panel is of the original dimension called for on the drawing. In ordinary procedures, if something is out of line, each succeeding item is cut to fit that particular part. This is impossible with organized house construction since parts are pre-cut.

The actual time required to tip up the exterior wall is very small compared to its fabrication time. No special equipment is needed nor is special handling required. From a standpoint of organization, it is better to tip two walls rather than tipping each one as it is completed.

Step 5: Select a roof truss designed for the span and loads involved. Proceed with the material schedule, pre-cutting, and assembly as on the walls.

The use of lightweight roof trusses or trussed rafters in house construction has been demonstrated many times as being one of the major important labor-saving techniques. The use of trusses also leads to many savings in other operations. Adequate designs for roof trusses are now available and are in form so that they are generally accepted by building code and insuring organizations. The first step in the use of roof trusses is to select the design, including the method of assembly (either ring connectors, nails, or glued gusset plates), and the type. Some truss designs call for all 2-inch lumber; others call for 1-inch webb members, etc.

Pre-cutting from schedule is carried on exactly as it is for the exterior walls, and the pre-assembly of the roof trusses is completed either on the subfloor or on a jig table. As in the pre-assembly and tip-up of exterior walls, one of the more difficult operations is to convince the workmen that the trusses are not heavy to handle and that the resulting frame is stronger and easier to build than a similar frame assembled in the more usual fashion. The actual weight of a truss of 25'-8" span is 135 pounds. For a span of 30'-0", the weight is only 200 pounds.

Step 6: Carry the assembly of the house through to the installation of finish material on walls and ceilings before any partitions are erected.

Once the roof is in place (see section on truss placement, page 20). it is essential that no partitions or other divisions of space be erected until the finish material has been installed on the entire ceiling and exterior walls. It is desirable to carry the trimming of windows and other operations as far as possible before any divisions are installed. As soon as the room is divided, working conditions are much less convenient for the carpenters. If a wood finish floor is being used, it can be laid over the entire area before partitions are tipped into place.

The use of drawings to determine the location of pieces of wallboard, similar to the framing drawings for wall studs, is a first and important step. Material lists of sizes and quantities follow the preparation of the drawings. The drawings should be furnished to the foreman, and he should be instructed to follow them.

Step 7: Repeat the procedures outlined in Steps 3, 4, and 6, applying the system to the various interior components.

The steps used in the assembly of the exterior walls and roof (called the "shell" in this report) are repeated in the division of space into rooms, the construction of cabinet work, and the fitting of closets. Drawings, framing schedules, material lists, pre-cutting, pre-assembly, and final positioning of the components of the interior of the house are accomplished in the same manner as described above for the shell. Variations will exist depending on the material or details used.

The component descriptions which follow give the procedures used for the demonstration houses. With slight modifications, they can be used in any structure.

COMPONENT PARTS OF DEMONSTRATION HOUSES

SITE, FOUNDATION, AND SLAB

Before any work was started on the site, a detailed study of the construction was conducted in the drafting room. Decisions made in the drafting room were based on past experience or on new construction techniques that were to be used. By such organization and pre-planning, field decisions by the workmen were held to a minimum, conflicts between different trades were reduced, and working conditions were improved for all trades.

With the latter in mind, a bulldozer was used to scrape the entire lot free of vegetation and debris. In the area that was to be occupied by the house and garage, 4 inches of top soil was removed and piled at the rear of the lot so that it would not interfere with the septic-tank installation, water-line trench, or the delivery of material. Four inches of soil was also removed from the driveway by the bulldozer, and the driveway was filled with pit run gravel to facilitate the delivery of materials. The gravel served as an under course for the finished drive.

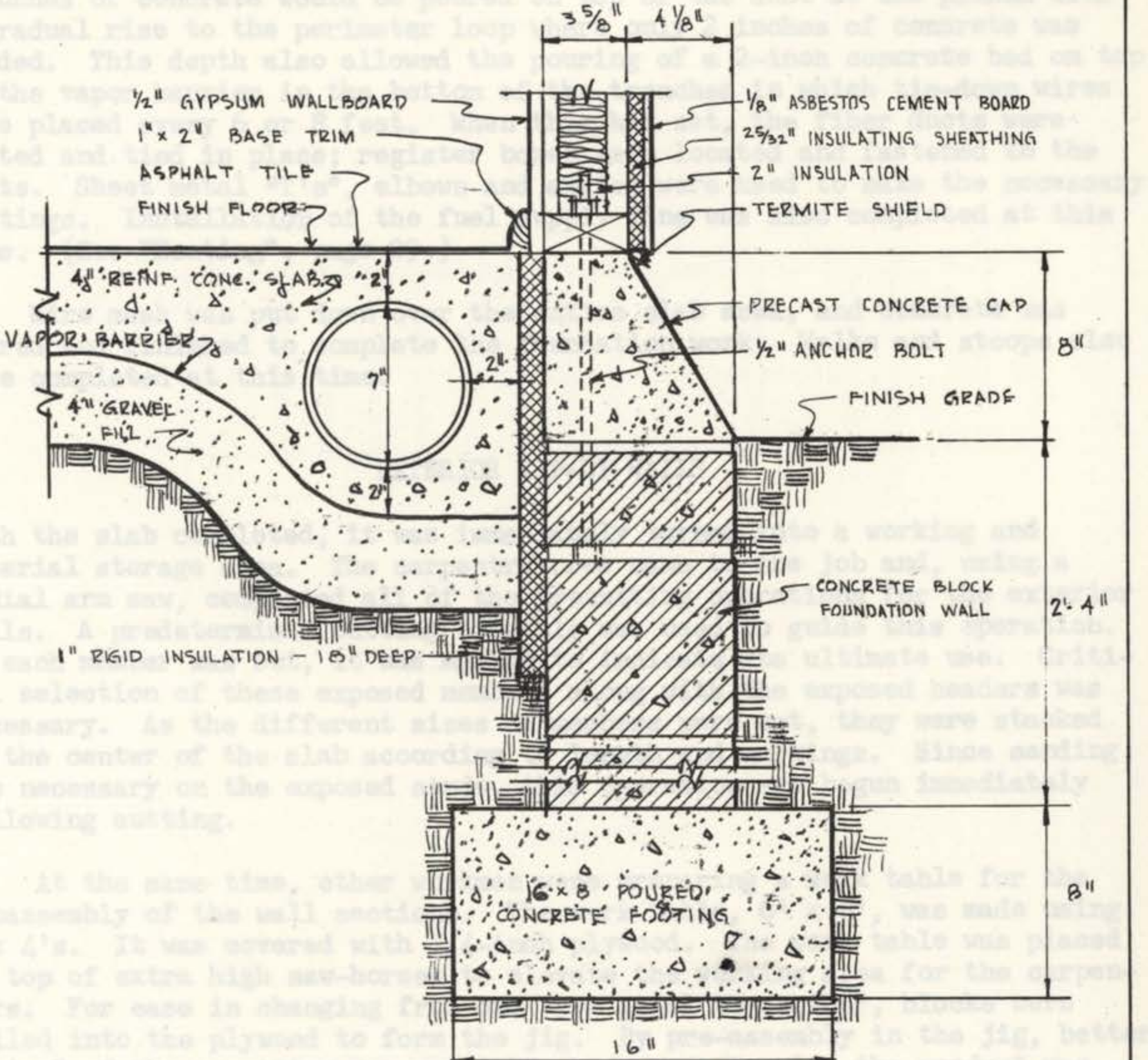
The house was set back 44 feet on the 70' x 132' lot, and the anticipated finished grade line was set 8 inches below the finished floor line as established by the batter boards and building lines. These lines were set on the batter boards to correspond with the inside measurements of the foundation wall and the finished floor line. This was feasible due to the shape of the foundation cap block.

Laborers excavated the footing trench to a width of 16 inches and to a depth of 44 inches below the building lines. All of the earth removed from the trenches was placed outside of the foundation wall to eliminate rehandling during the installation of heat ducts, and also to eliminate the job of tamping which is necessary when earth is used as fill under concrete slab floors.

By digging the trenches in this manner and utilizing the firm characteristics of the soil, no forms were necessary for the pouring of the 16" x 8" concrete footings. The mason transferred corner markings from the building lines to the footings, and corners of the concrete block foundation wall were started. The wall nearest the plumbing wall was laid up as the No. 1 wall to form a base line for the plumber. This allowed the plumber to lay out and start the underfloor plumbing. (See "Plumbing," page 28.)

The mason chose to make the 4" x 8" x 16" cap blocks on the job and he used wooden wedges to align them on the foundation wall. (To set them, he used a mortar gun which forced mortar between the joints.) By using a block of this design, the edge insulation could be placed in the vertical position without cutting the insulation. This operation was done as gravel fill was being dumped inside the foundation wall. Gravel was placed along the bottom edge of the insulation to hold it in place. (See drawing, page 15.)

By locating and installing the plenum chamber for the furnace at this time, trenches for the fiber heating ducts could be left open and filled to the proper depth. When the concrete was poured, it was regulated so that



SLAB & FOUNDATION DETAIL

SCALE: 1 1/2" = 1'-0"

DEMONSTRATION HOUSE — UNIVERSITY OF ILLINOIS SMALL HOMES COUNCIL

5 inches of concrete would be poured on top of the duct at the plenum with a gradual rise to the perimeter loop where only 2 inches of concrete was needed. This depth also allowed the pouring of a 2-inch concrete bed on top of the vapor barrier in the bottom of the trenches in which tie-down wires were placed every 6 or 8 feet. When this had set, the fiber ducts were fitted and tied in place; register boxes were located and fastened to the ducts. Sheet metal "T's", elbows and angles were used to make the necessary fittings. Installation of the fuel supply line was also completed at this time. (See "Heating", page 29.)

Wire mesh was put down over the entire slab area, and concrete was poured and finished to complete the foundation work. Walks and stoops also were completed at this time.

EXTERIOR TIP-UP WALLS

With the slab completed, it was immediately turned into a working and material storage area. The carpentry crew came to the job and, using a radial arm saw, completed all of the precutting operations for the exterior walls. A predetermined cutting schedule was used to guide this operation. As each member was cut, it was marked to indicate its ultimate use. Critical selection of these exposed members along with the exposed headers was necessary. As the different sizes of members were cut, they were stacked in the center of the slab according to length and markings. Since sanding was necessary on the exposed studs, this operation was begun immediately following cutting.

At the same time, other workmen were preparing a work table for the subassembly of the wall sections. The work table, 6' x 8', was made using 2 x 4's. It was covered with 3/4-inch plywood. The work table was placed on top of extra high saw-horses to elevate the working area for the carpenters. For ease in changing from one type panel to another, blocks were nailed into the plywood to form the jig. By pre-assembly in the jig, better control of the operation was possible, and, as a result, the product was better finished. Twenty 4-foot window and door sections were made in the jig, moved to a position adjacent to the concrete slab, and primed.

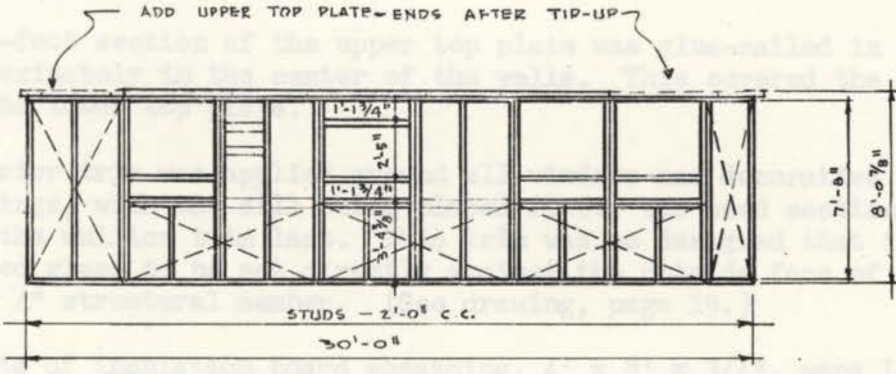
Each wall was assembled near the position it was to occupy in the finished house, thus eliminating the need for rehandling. Opposite walls were constructed at the same time for better utilization of the working crew.

The following were the steps used in the assembly process:

1. Two chalk lines were snapped on the slab, indicating the bottom of the lower plate and the top of the lower member of the double top plate.

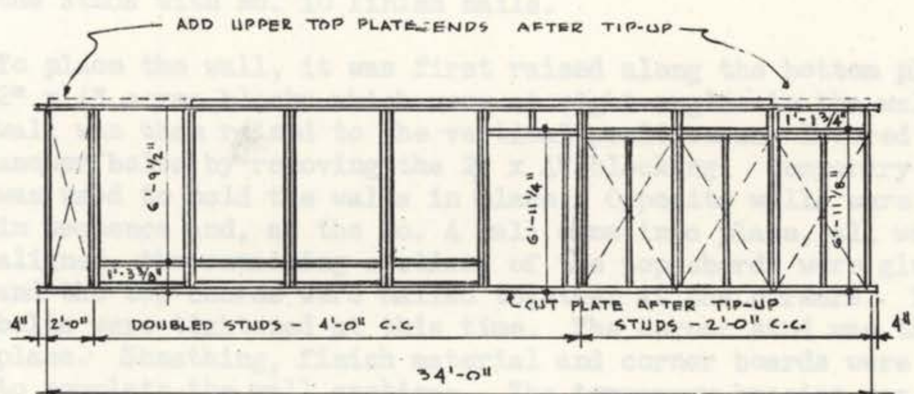
2. Top and bottom plates were placed along these lines.

3. Centers at 2 feet were marked on both top and bottom plates. Marking was done from one end of each wall section with a steel tape. Anchor bolt notches were cut in the bottom chords.



TIP-UP NO. 3 - EAST WALL
SCALE: 1/8" = 1'-0"

NOTE
DIAGONAL BROKEN LINES
INDICATE PANEL OF 1/8"
ASBESTOS CEMENT SIDING



TIP-UP NO. 2 - SOUTH WALL
SCALE: 1/8" = 1'-0"

4. The pre-assembled 4-foot window and door sections were placed in position between the plates along with the regular studs, and were end-nailed through the top and bottom plates.

5. All double studs were nailed together at 12-inch intervals. Finish nails were used to nail exposed studs together.

6. A 16-foot section of the upper top plate was glue-nailed in position approximately in the center of the walls. This covered the joint in the lower top plate.

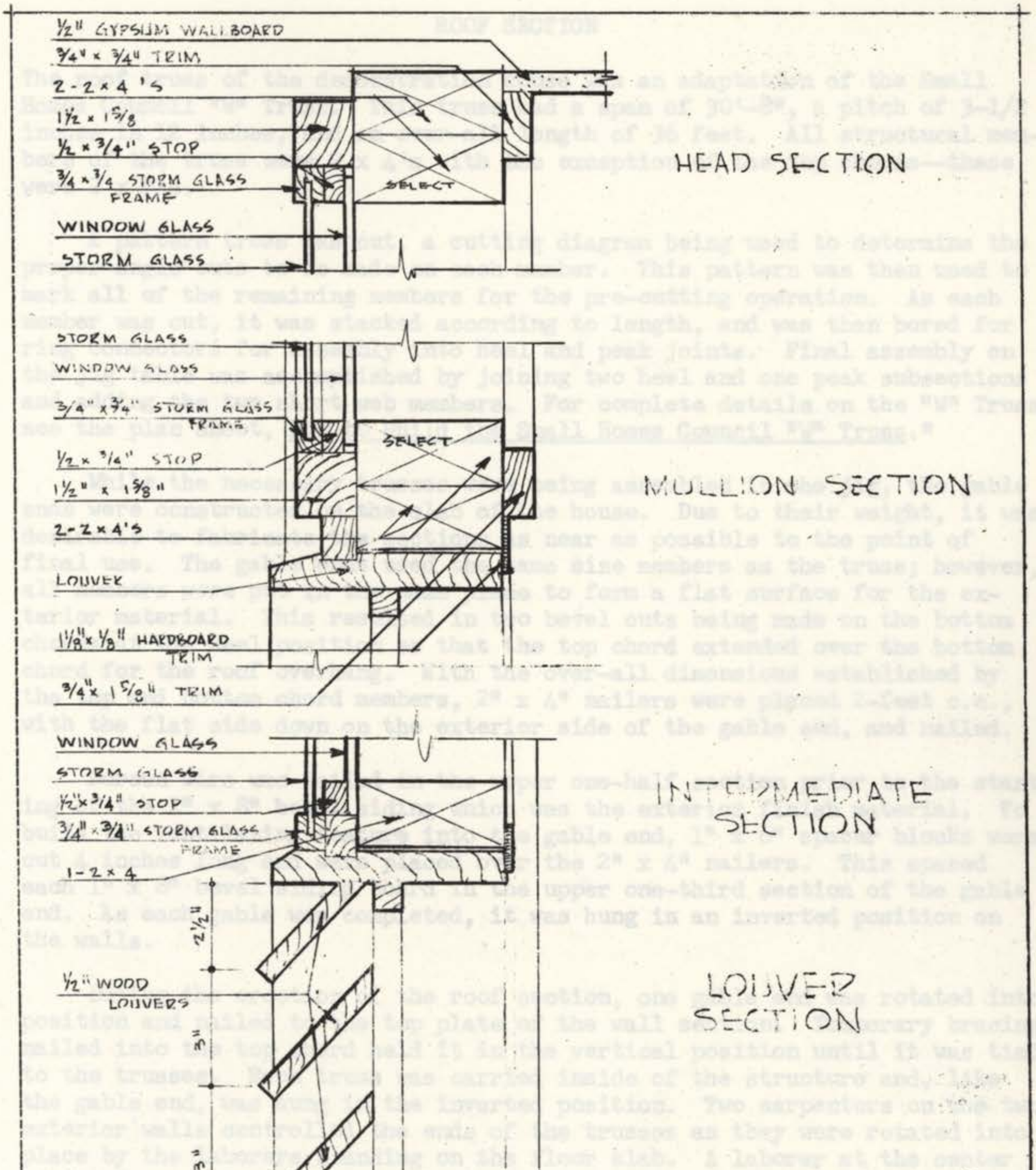
7. Exterior trim was applied around all windows and decorative panel openings, with the sill being placed first, the head section next, and the mullion trim last. This trim was so designed that it permitted glass to be set directly against the outside face of the 2" x 4" structural member. (See drawing, page 19.)

8. Sheets of insulation board sheathing, 4' x 8' x 3/4", were laid on the framing, slipped under the routed sills, and nailed with 1-1/4-inch roofing nails. All joints occurred over studs.

9. Sheets of asbestos cement, 4' x 8' x 1/8", were applied directly over the sheathing. Joints occurred over studs but no joints occurred over a joint in the sheathing. (See drawing, page 17.) A bead of caulking was run over the sheathing where a joint occurred in the asbestos cement. Where butt joints between the asbestos cement and the mullion occurred (i.e., around windows), caulking beads were run under the asbestos cement. No drilling was necessary to nail through the asbestos cement to the studs. Decorative panels were handled in the same fashion.

10. The 1" x 2" frieze was placed and nailed. Pre-cut battens were placed over all studs, butted against the frieze, and nailed into the studs with No. 10 finish nails.

11. To place the wall, it was first raised along the bottom plate on 2" x 4" scrap blocks which were at right angles to the wall. The wall was then raised to the vertical position and lowered over the anchor bolts by removing the 2" x 4" blocking. Temporary bracing was used to hold the walls in place. Opposite walls were erected in sequence and, as the No. 4 wall came into place, all walls were aligned, the remaining sections of the top chords were glue-nailed, and the top chords were nailed together at the corners. The anchor bolts were tightened at this time. The corner stud was then put in place. Sheathing, finish material and corner boards were applied to complete the wall sections. The temporary bracing was not removed until after the trusses were erected.


1/2" GYPSUM WALLBOARD
3/4" × 3/4" TRIM
2-2×4'S
1/2 × 1 5/8
1/2 × 3/4" STOP
3/4 × 3/4 STORM GLASS FRAME
SELECT
HEAD SECTION
WINDOW GLASS
STORM GLASS
STORM GLASS
WINDOW GLASS
3/4" × 3/4" STORM GLASS FRAME
SELECT
1/2 × 3/4" STOP
1 1/2" × 1 5/8"
MULLION SECTION
2-2×4'S
LOUVER
1 1/8" × 1/8" HARDBOARD TRIM
3/4" × 1 5/8" TRIM
WINDOW GLASS
STORM GLASS
INTERMEDIATE SECTION
1/2"×3/4" STOP
3/4" × 3/4" STORM GLASS FRAME
1-2×4
1/2" WOOD LOUVERS
LOUVER SECTION
2-2×4'S
SILL SECTION
1 5/8" × 1 3/4" SILL
1" × 1 5/8" TRIM
DEMONSTRATION HOUSE — UNIVERSITY OF ILLINOIS SMALL HOMES COUNCIL

ROOF SECTION

The roof truss of the demonstration house was an adaptation of the Small Homes Council "W" Truss. This truss had a span of 30'-8", a pitch of 3-1/2 inches in 12 inches, and an over-all length of 36 feet. All structural members of the truss were 2 x 4's with the exception of the top chords--these were 2 x 6's.

A pattern truss was cut, a cutting diagram being used to determine the proper angle cuts to be made on each member. This pattern was then used to mark all of the remaining members for the pre-cutting operation. As each member was cut, it was stacked according to length, and was then bored for ring connectors for assembly into heel and peak joints. Final assembly on the jig table was accomplished by joining two heel and one peak subsections and adding the two short web members. For complete details on the "W" Truss, see the plan sheet, How to Build the Small Homes Council "W" Truss.*

While the necessary trusses were being assembled in the jig, the gable ends were constructed on the slab of the house. Due to their weight, it was desirable to fabricate the sections as near as possible to the point of final use. The gable ends used the same size members as the truss; however, all members were put in the same plane to form a flat surface for the exterior material. This resulted in two bevel cuts being made on the bottom chords at the heel position so that the top chord extended over the bottom chord for the roof overhang. With the over-all dimensions established by the top and bottom chord members, 2" x 4" nailers were placed 2-feet o.c., with the flat side down on the exterior side of the gable end, and nailed.

Screen wire was nailed in the upper one-half section prior to the starting of the 1" x 8" bevel siding which was the exterior finish material. To build the ventilating feature into the gable end, 1" x 6" spacer blocks were cut 4 inches long and were placed over the 2" x 4" nailers. This spaced each 1" x 8" bevel siding board in the upper one-third section of the gable end. As each gable was completed, it was hung in an inverted position on the walls.

During the erection of the roof section, one gable end was rotated into position and nailed to the top plate of the wall section. Temporary bracing nailed into the top chord held it in the vertical position until it was tied to the trusses. Each truss was carried inside of the structure and, like the gable end, was hung in the inverted position. Two carpenters on the two exterior walls controlled the ends of the trusses as they were rotated into place by the laborers standing on the floor slab. A laborer at the center of the truss held it in a vertical position until continuous tie boards could be nailed on the top chords at points approximately halfway up the top chord members. Each truss was rotated by this method and secured to the wall plate on 2-foot centers by the carpenters while the next truss was brought in by the rest of the crew. In order to provide ample room for rotating the second gable end, the last three trusses were rotated and leaned against the last upright truss that had been fastened to the wall. After

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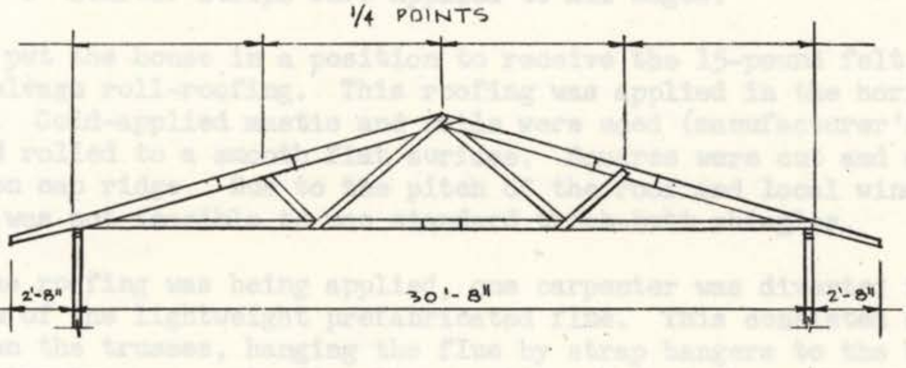
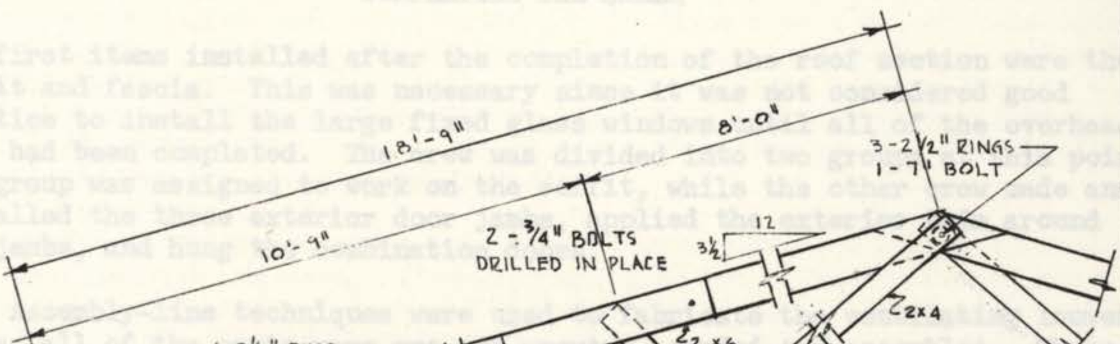
* Available from the Small Homes Council, University of Illinois, Mumford House, Urbana, Illinois, for 25 cents.



"W" TRUSS
SCALE: 1/8"=1'-0"



TRUSS DETAIL
SCALE: 3/8"=1'-0"

the gable end came into position, these trusses were moved along the top plate to their respective positions and nailed. Temporary bracing on the wall sections was then removed.

To enclose the structure as soon as possible for protection against the elements, 1" x 6" T&G sheathing was applied immediately following the truss erection. The sheathing ends were trimmed with a portable hand saw, and metal "T" starter strips were applied to all edges.

This put the house in a position to receive the 15-pound felt, and the 19-inch selvage roll-roofing. This roofing was applied in the horizontal direction. Cold-applied mastic and nails were used (manufacturer's directions) and rolled to a smooth flat surface. Squares were cut and applied as a Boston cap ridge. Due to the pitch of the roof and local wind conditions, it was not feasible to use standard thick-butt shingles.

As the roofing was being applied, one carpenter was diverted to the installation of the lightweight prefabricated flue. This consisted of blocking between the trusses, hanging the flue by strap hangers to the bottom chords of two trusses, extending the sections 2 feet above the ridge of the roof, and installing the flue housing. Completing this operation at this point eliminated flashing problems around the flue housing.

(For the roughing-in wiring work at this time, see "Wiring", page 29.)

COMPLETING THE SHELL

The first items installed after the completion of the roof section were the soffit and fascia. This was necessary since it was not considered good practice to install the large fixed glass windows until all of the overhead work had been completed. The crew was divided into two groups at this point. One group was assigned to work on the soffit, while the other crew made and installed the three exterior door jambs, applied the exterior trim around the jambs, and hung the combination doors.

Assembly-line techniques were used to fabricate the ventilating louver units; all of the parts were pre-cut, routed, sanded and assembled. These units were set in a bead of caulking in the rough openings of the wall and were nailed. The fixed glass was purchased on an in-place basis so while it was being installed by the vendor, one of the carpenters made the permanent window stops. He then removed the temporary stops and embedded the stops in a bead of caulking before nailing. This operation completely enclosed the structure as one large room. Protection against the weather was thus provided, as well as an inside working area for the crew, and storage space for equipment and some material.

The first job scheduled for the carpentry crew after the structure had been enclosed was that of insulating the side walls. Semi-thick 23" x 48" batts were used and were held in place by an industrial stapling gun.

While the house was one large open room, the entire ceiling wallboard (1/2-inch foilback gypsum wallboard) was applied to the lower chords of the trusses. Study of the wallboard layout showed that it was possible to use large size sheets (all sheets were 4' x 10's or 4' x 12's). This reduced the number of joints to be treated and also the number of pieces of wallboard material to be handled by the workmen. (See drawing, page 24.) No elaborate scaffolding or material-holding devices were used on this operation.

The application of wallboard on the exterior side-walls followed immediately after the ceiling operation. Here again sizes of material that required the least amount of cutting and fitting were used. This wallboard was applied directly to the inside face of the stud in the horizontal direction. Contrary to the usual practice of applying the top sheet of wallboard first, the procedure was reversed as an aid to the workmen since the lower sheet held the weight of the top sheet. Construction details calling for a ceiling height of 8'-0½" after the finish ceiling material was applied permitted any irregularities to be covered by the 2-1/2-inch base trim and the 2-inch ceiling trim.

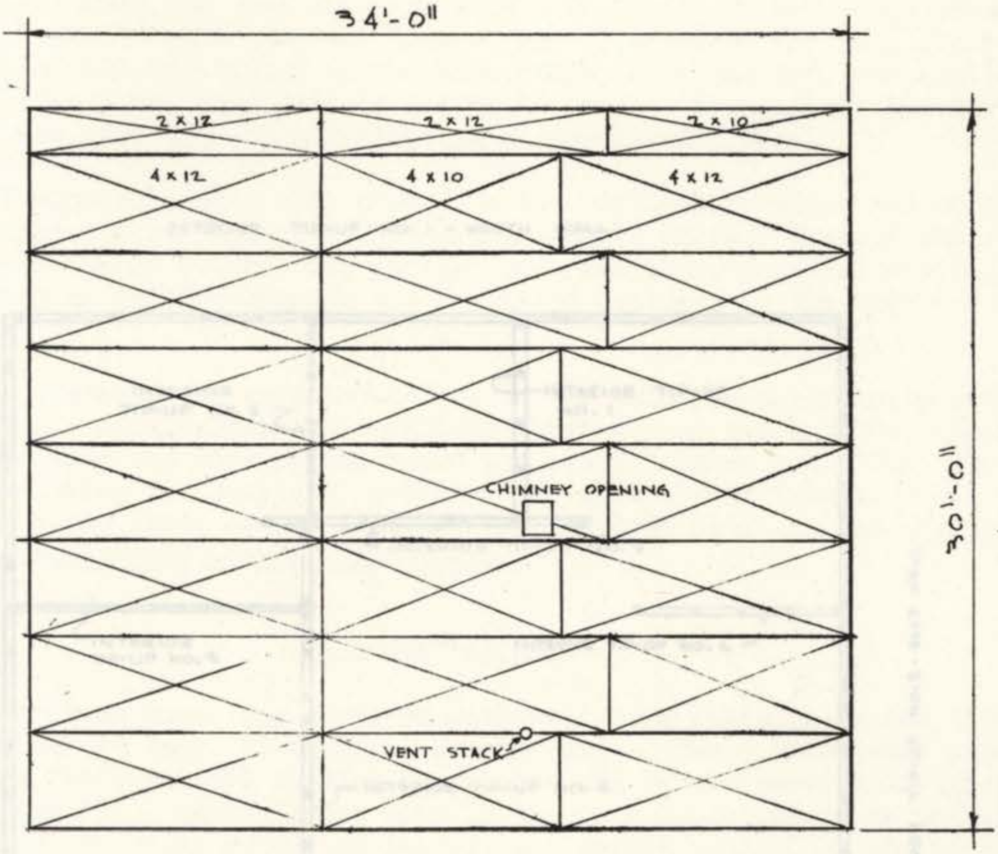
INTERIOR PARTITIONS

Framing for the partitions was started after the wallboard had been applied to the exterior walls and to the ceiling. The No. 1 wall to be placed was the plumbing wall dividing the kitchen and the bathroom. This wall was built in two sections, one on each side of the plumbing tree, but a common top and bottom plate was used. These plates were put in place, and 2" x 2" studs were placed on each edge of the plates and nailed. This eliminated the usual notching of the studs in the plumbing wall. From pre-cut parts, all other partitions were constructed on the floor near the positions they were to occupy. Upon completion, they were tipped into place and nailed to the floor with tempered steel nails. Shims were placed between the top plate and the finish ceiling material before nailing into the ceiling blocking or the bottom chord of the truss. Shimming was necessary since 1/2-inch clearance was needed for the tipping operation.

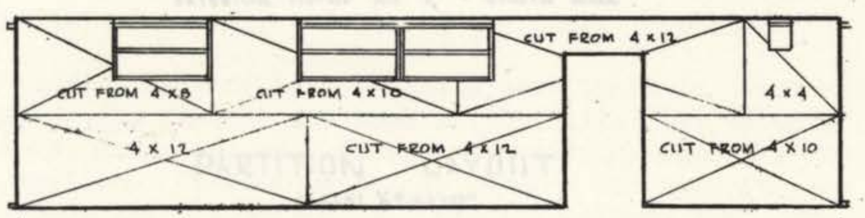
During the planning stage, each partition was given a number to designate the erection sequence. (See drawing, page 25.) This numbering plan allowed for adequate work space in the vicinity of the partition plus ample room for nailing from one partition to the other. No attempt was made to apply the wallboard to the partition framing before it was tipped into place due to the need for nailing space and the need for bringing the wiring to the outlets.

STORAGE UNITS

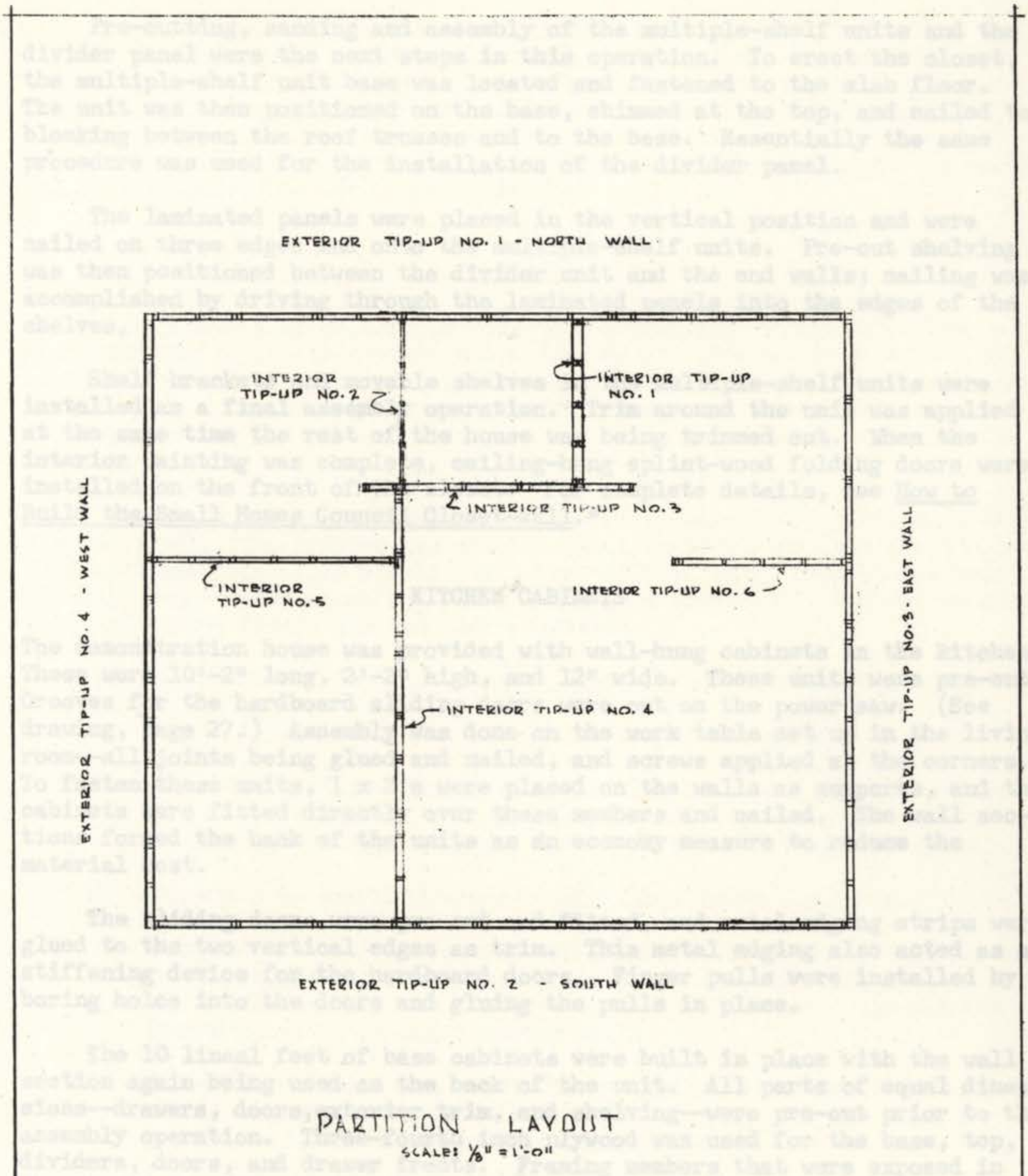
As the first step in the assembly of the closet-wall units, the thin-wall panels were laminated. (This consisted of gluing a 4' x 8' x 3/8" sheet of gypsum board to a 4' x 8' x 1/8" sheet of tempered hardboard with linoleum paste.) These were laminated on the floor slab in the bedroom section of the house since it was necessary to place weights on the panels for a 24-hour period before erection. With the partition wall serving as a back for the closet in bedroom No. 1, it was necessary to fabricate only three thin-wall panels for the closet separating bedrooms No. 2 and No. 3. (See Floor Plan, page 3, for location.)



CEILING GYPSUM BOARD LAYOUT
SCALE: 1/8" = 1'-0"



INTERIOR ELEVATION — EXTERIOR TIP-UP NO 1
SCALE: 1/8" - 1'-0"


EXTERIOR TIP-UP NO. 1 - NORTH WALL
INTERIOR TIP-UP NO. 2
INTERIOR TIP-UP NO. 1
INTERIOR TIP-UP NO. 3
INTERIOR TIP-UP NO. 5
INTERIOR TIP-UP NO. 6
INTERIOR TIP-UP NO. 4
EXTERIOR TIP-UP NO. 4 - WEST WALL
EXTERIOR TIP-UP NO. 3 - EAST WALL
EXTERIOR TIP-UP NO. 2 - SOUTH WALL
PARTITION LAYOUT
SCALE: 1/8" = 1'-0"
DEMONSTRATION HOUSE —— UNIVERSITY OF ILLINOIS - SMALL HOMES COUNCIL

Pre-cutting, sanding and assembly of the multiple-shelf units and the divider panel were the next steps in this operation. To erect the closet, the multiple-shelf unit base was located and fastened to the slab floor. The unit was then positioned on the base, shimmed at the top, and nailed to blocking between the roof trusses and to the base. Essentially the same procedure was used for the installation of the divider panel.

The laminated panels were placed in the vertical position and were nailed on three edges and onto the multiple-shelf units. Pre-cut shelving was then positioned between the divider unit and the end walls; nailing was accomplished by driving through the laminated panels into the edges of the shelves.

Shelf brackets and movable shelves in the multiple-shelf units were installed as a final assembly operation. Trim around the unit was applied at the same time the rest of the house was being trimmed out. When the interior painting was complete, ceiling-hung splint-wood folding doors were installed on the front of the closet. For complete details, see <u>How to Build the Small Homes Council Closet-Wall</u>.*

KITCHEN CABINETS

The demonstration house was provided with wall-hung cabinets in the kitchen. These were 10'-2" long, 2'-2" high, and 12" wide. These units were pre-cut. Grooves for the hardboard sliding doors were cut on the power saw. (See drawing, page 27.) Assembly was done on the work table set up in the living room--all joints being glued and nailed, and screws applied at the corners. To fasten these units, 1 x 2's were placed on the walls as supports, and the cabinets were fitted directly over these members and nailed. The wall sections formed the back of the units as an economy measure to reduce the material cost.

The sliding doors were pre-cut and fitted, and metal edging strips were glued to the two vertical edges as trim. This metal edging also acted as a stiffening device for the hardboard doors. Finger pulls were installed by boring holes into the doors and gluing the pulls in place.

The 10 lineal feet of base cabinets were built in place with the wall section again being used as the back of the unit. All parts of equal dimensions--drawers, doors, exterior trim, and shelving--were pre-cut prior to the assembly operation. Three-fourth inch plywood was used for the base, top, dividers, doors, and drawer fronts. Framing members that were exposed in the finished cabinet were white pine.

For the work surface on top of the cabinets, a field-applied plastic material was used and was capped with metal edging strips.

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* Available from the Small Homes Council, University of Illinois, Mumford House, Urbana, Illinois, for 25 cents.

The 8 feet of storage cabinets in the kitchen were built in place using the divider panels as described under closet walls. This divided the 8-foot section into four 2-foot units. One unit housed the hot-water tank; one unit was a broom closet; and the other two were for shelf storage. (See floor plan for location, page 3.) At 5'-6" above the floor, a divider was run horizontally. Eight doors made from plywood were hung to the vertical divider panels to enclose the closets.

PLUMBING

The plumbing was a subcontracted job. The scheduling of the work along with the outlining of specific items to be done by the plumber at certain construction stages were the main items considered during the pre-planning phase of the study. Scheduling was required in order to eliminate unnecessary trips to the job and also to eliminate one trade interfering with the work of another.

Because the mason laid the foundation wall nearest the plumbing wall as the No. 1 wall, the plumber was able to use this as a base line for the location of his pipes. By starting his work at this time, very little hand trenching was needed since the final dumping of gravel-fill was not scheduled until after the foundation had been completed.

During his first visit to the site, the plumber did the following:

1. Put in a 3/4-inch water service to the street main.
2. Ran all underfloor drains to a distance of 5 feet outside of the foundation wall; built a plumbing tree of the drain and vent pipes to a height of approximately 4 feet in the plumbing wall space.
3. Ran all hot- and cold-water supply lines under the floor.
4. Extended the hot- and cold-water lines in the plumbing wall to their proper height and location. These pipes were fabricated along with the drains so that the fixture branches would extend through the finish material on the plumbing wall.
5. Extended the drain and supply lines coming up through the floor at points other than in the plumbing wall location to a height of approximately 4 inches above the finish floor line, and capped them.
6. Joined the hot- and cold-water supply lines with a temporary connection; turned on water pressure for test purposes and also to supply construction water at the center of the site.
7. Tested the drain lines.

After the shell of the house had been completed and the framing of the partitions erected, the plumber returned to the site and—

1. Extended the two vents through the roof section.

2. Extended the two frost-proof sill cocks through the exterior walls.

3. Set the bathtub and extended the pipes for the shower head and controls.

4. Delivered the kitchen sink and the lavatory.

Prior to the plumber's third trip to the job, the carpenters built the kitchen and lavatory cabinets, installed the fixtures in these units, and applied the cabinet-top finish material. Tiling of the bathroom wall was also completed. This made it possible for the plumber to finish the job by connecting the fixtures and installing the water closet, electric hot-water heater and the water meter.

HEATING

The heating system for the demonstration houses was a warm-air, perimeter system. The heating contracts were divided so that the masonry subcontractor was to install the underfloor ducts but was to be supplied with the register boots, metal fittings and the plenum by the heating subcontractor. These were fabricated in the shop of the heating subcontractor and delivered to the job during the foundation work.

The heating unit did not have to be put in operation immediately following the enclosing of the house since this building operation was conducted during the summer; however, this could have been accomplished without any difficulty. The heating contractor was not called to the site until after all of the partitions, trim, etc. were in place. The framing that formed the enclosure of the furnace space was left open at the front and rear to allow working room during the setting of the furnace. The furnace installed was an oil-fired, pot-type, counter-flow unit with a 64,000 B.T.U. rating. This was located directly over the plenum and connected to the previously installed lightweight flue. Connections were made to the oil line coming from under the floor and to the electrical outlet provided. While the two workmen were setting the furnace, another workman was burying the oil storage tank near the kitchen wall. The tank was covered with earth after the connections had been made and it was filled immediately to prevent floating.

After the ducts were cut out through the register boots and the registers installed, the furnace was started, oiled, and tested.

WIRING

The first operation of the electrician was scheduled to be completed while the carpentry crew was working on the roofing. (Some codes may delay this until the building is enclosed.) Scheduling was arranged in this sequence in order that the electrician could work inside the house without interference from the other trades.

During this time, the electrician erected the service pole, set the fuse panel, installed switches and duplex outlets in the exterior wall, installed the kitchen exhaust fan, and ran all lines. The lines to the exterior walls were wired into the panel and connected so that power would be available for the electrical equipment set up within the house. Wires to outlets specified on interior partitions were cut to length, coiled and placed on the top of truss bottom chords.

When the carpenters were completing the framing and tip-up of the interior partitions, the electrician returned to the job and dropped the wires from the attic through the partition top plates. He also installed the outlets and switches. (Close coordination between the carpentry crew and the electrician was essential at this point due to the wallboard application on the partitions immediately following their erection.) The ceiling boxes were also installed and connected.

On the electrician's third trip to the site, there was no scheduling problem as the work was a simple finishing operation. This consisted of installing the fixtures, wiring in the medicine cabinet lights, and applying duplex and switch face-plates.

EQUIPMENT

Power Equipment

Power equipment used during the construction of the demonstration houses was considered the minimum required for contractors who build from one to ten houses per year. Throughout this project, the workmen were encouraged to use this equipment whenever possible. So that they would make use of it, the equipment was always placed conveniently near the place they were working.

The power equipment consisted of:

1. 10" - one horsepower radial arm saw with extension table. (See following paragraph.)

2. 8" - one horsepower portable hand saw.

3. 6" - one-half horsepower portable joiner.

4. 1/2" - slow-speed, heavy-duty drill.

5. 1/4" - high-speed drill.

6. 2" - belt sander.

7. Oscillating sander.

8. Attachments to the above. These consisted of drills, a cutter head for boring the ring connector grooves in the truss members, and the usual amount of saw blades, including a dado set for the radial arm saw.

The radial arm saw and the joiner were the two items used most frequently in this project, the other items becoming secondary and being used for specific jobs. It was noted that the radial arm saw with the one horsepower motor rating was too small. This resulted in the motor overheating during continuous ripping operations on materials above the 1-inch dimension. In the equipment listed above, an increase in the size of the power unit on the radial arm saw is the only change recommended.

<u>Hand Tools</u>

Each carpenter on the job had an average amount of general carpentry tools which he furnished for his own use. The only hand tool furnished by the contractor was a wood trimmer. This trimmer was used in lieu of a mitre box and proved very successful in making accurate cuts and joints at any angle. It was portable and was used both inside and outside.

<u>Use of Work Tables and Jigs</u>

This particular phase of the study sought to achieve the best possible results in the way of quality production without a corresponding increase in labor costs. To achieve this, an elevated work table and jig were used in fabricating the subsection of the exterior walls. The time expended in setting up this jig more than paid for itself in that it reduced a subsequent operation by 14 man-hours and resulted in a better finished product.

A jig was also used to assemble the truss sections. This resulted in a more uniform product and the elimination of nail holes in the concrete slab. It also kept the slab free for the fabrication of the gable end sections which were assembled at the same time. The latter provided separation and better utilization of the working crew. When the exterior of the house was completed, the crew moved to the interior and set up the power equipment and a work table in the area that was to be the living room. From this location, the interior work proceeded with a minimum waste in man-hours and effort by the crew.

MAN-HOUR COST

FOUNDATION AND SLAB

Component	Skilled	Unskilled	Machine	Total
1. Earth Preparation			2	2
2. Layout				
Staking and Batterboards	9-1/4	13-1/4		22-1/2
3. Excavation				
Footing Trenches		34		34
4. Foundations	68-1/2	62-1/4		130-3/4
5. Floor				
Duct placing, fill, vapor barrier, wire mesh, concrete finishing	28-3/4	54-1/4	1-1/2	84-1/2
TOTAL	106-1/2	163-3/4	3-1/2	273-3/4

SHELL

Component	Skilled	Unskilled	Machine	Total
6. Wall Framing				
Building	20-3/4	4-1/2		25-1/4
Erection	25-1/4	3-3/4		29
Sheathing	5-3/4	1-1/2		7-1/4
Siding	32	6-1/2		38-1/2
Gable End (total)	19-1/4	5		24-1/4
Louvers	67-1/2	5-1/4		72-3/4
TOTAL	170-1/2	26-1/2		197
7. Roof Framing				
Trusses	35-1/4	11-3/4		47
Sheathing	20-1/4	4-1/4		24-1/2
Roofing	37-3/4	11		48-3/4
TOTAL	93-1/4	27		120-1/4
8. Exterior Trim	18-1/2			18-1/2
10. Exterior Windows				
Sills, stops, fixed glass, exterior trim	40-3/4	6-1/2		47-1/4
14. Exterior Doors				
Storm doors only	7-3/4	1/4		8
19. Flue	5-3/4			5-3/4
TOTAL	336-1/2	60-1/4		396-3/4

MAN-HOUR COST

FINISH OPERATION

	Component	Skilled	Unskilled	Machine	Total
5.	Finish Floor	36			36
9.	Partitions	16-3/4			16-3/4
10.	Windows - Interior Trim	28			28
12.	Insulation	8-3/4	1/4		9
13.	Wallboard	97-3/4	34-1/4		132
14.	Doors	57-1/4	2-1/4		59-1/2
16.	Cabinets	82	1		83
17.	Closet-wall Units	111-1/2	7-3/4		119-1/4
30.	Miscellaneous	2	36-1/2		38-1/2
	TOTAL	440	82		522

Excludes:
- 11. Wiring
- 15. Septic Tank
- 18. Painting
- 20. Plumbing
- 21. Heating
- 22. Garage
- 23. Walks & Drives
- 24. Grading
- 27. Storm Sash

MAN-HOUR BREAKDOWN

Component	Skilled	Unskilled	Machine	Total
Slab Total	106-1/2	163-3/4	3-1/2	273-3/4
Shell Total	336-1/2	60-1/4		396-3/4
Finish Operation Total	440	82		522
TOTAL				1192-1/2
Accessories:				
Fence				
Garage				
Walks & Drives				
Grading				
Storm Windows				
TOTAL	196-1/2	173-1/2	9	379
TOTAL MAN-HOURS	1079-1/2	479-1/2	12-1/2	1571-1/2

SUMMARY

MAN-HOUR BREAKDOWN

	Component	Skilled	Unskilled	Machine	Total
1.	Earth Preparation			2	2
2.	Layout	9-1/4	13-3/4		23
3.	Excavation		34		34
4.	Foundations	68-1/2	62-1/4		130-3/4
5.	Floor	56-3/4	102-1/2	1-1/2	160-3/4
6.	Exterior Walls	170-1/2	26-1/2		197
7.	Roof Framing	89	27		116
8.	Exterior Trim	18-1/2			18-1/2
9.	Partitions	23-1/2			23-1/2
10.	Windows	56-1/2	6-1/2		63
11.	Wiring				
12.	Insulation	8-3/4	1/4		9
13.	Wallboard	97-3/4	34-1/4		132
14.	Doors	65	2-1/2		67-1/2
15.	Septic Tank				
16.	Cabinets	82	1		83
17.	Closet-wall Units	111-1/2	7-3/4		119-1/4
18.	Painting				
19.	Flue	5-3/4			5-3/4
20.	Plumbing				
21.	Heating				
22.	Garage	155-1/2	65-3/4		221-1/4
23.	Walks & Drives	47-3/4	31-1/2		79-1/4
24.	Rough Grading		27-1/2	9	36-1/2
26.	Bath Tile				
27.	Storm Windows	11			11
30.	Miscellaneous	2	36-1/2		38-1/2
	TOTAL	1079-1/2	479-1/2	12-1/2	1571-1/2

Note: Figures not listed were all subcontracted items.

SAMPLE ORDER-SCHEDULE
BY COMPONENTS

Component	Order
4. Foundations	
B. Footings	132 lin. ft.
1. House - 16" x 8"	(4 cu. yds.)
C. Blocks - 8 x 8 x 16	294
4 x 8 x 16	98
Precast Caps - 4 x 8 x 16	98
D. Insulation	
12" x 36" x 1" A.E. Perimeter Insulation	128 lin. ft.
E. Termite Shield	
1 roll - 10" - oz. Copper Armoured Kraft Paper	120 lin. ft.
F. Anchor Bolts, 1/2 x 12	16
5. Floor	
A. Heat Ducts - Subcontract	
Boots - 4" x 14"	11
Boots - 6" x 8" x 18" - Kitchen	1
Adjustable Elbows	14
Air Ducts - 7"	250 lin. ft.
B. Fill	
Gravel Fill - Pit Run	15 cu. yds.
C. Vapor Barrier	
Kraft Paper - 1-1/2 roll - 8' width	1500 sq. ft.
D. Concrete & Wire Mesh	
Concrete - 1-2-3 mix	15 cu. yds.
Wire Mesh - #10 - 1-1/2 rolls	1500 sq. ft.
E. Finish Floor, 9" x 9" x 1/8"	
"C" Grade Asphalt Tile	950 sq. ft.
6. Exterior Walls	
A. Framing - Wall 1.	
21 - Studs - 2 x 4 x 7' - 7-5/8"	
1 - Stud - 2 x 4 x 6' - 7-1/2"	
3 - Studs - 2 x 4 x 5' - 5-3/4"	
9 - Headers - 3' - 8-3/4"	See Cutting
4 - Top Plates - 2 x 4 x 18	and Order
2 - Bottom Plates - 2 x 4 x 18	Schedule
2 - Blocking - 2 x 4 x 1' - 9-1/2"	
1 - Blocking - 2 x 4 x 0' - 10-1/2"	
2 - Blocking - 2 x 4 x 0' - 7-1/4"	

HHFA DEMONSTRATION HOUSES

Exterior Walls - Sample Cutting and Order Schedule

SIZE 2 x 4 x -	NO. REQ.	WHERE USED	CUT FROM 2 x 4 x -	WASTE	USE WASTE FOR	BUY
7'-8"	21 19 18 17 4 79	Wall 1 Wall 2 Wall 3 Wall 4 Corners	79-7'-11"	79-0'-3"	Scrap	79-7'-11"
18'-0"	12	Top & Bottom Plates Walls 1 & 2	12-18'-0"	None	None	12-18'-0"
16'-8"	6	Top & Bottom Plates Walls 1 & 3	6-18'-0"	6-1'-3"	Stock Pile	6-18'-0"
12'-0"	4	Top & Bottom Plates Walls 2 & 4	4-12'-0"	None	None	4-12'-0"
12'-8"	2	Top Plates Walls 2 & 4	2-18'-0"	2-5'-3"	2-4'-3"	2-18'-0"
6'-8"	3	Doors Walls 1, 3 & 4	3-18'-0"	3-11'-4"	3-6'-5-7/8"	3-18'-0"
6'-6-3/8"	3	Studs Wall 3	Surplus 3-11'-4"	3-4'-9"	3-4'-2-1/2"	None
5'-6-1/4"	3	Studs Wall 1	1-18'-0"	1-1'-4"	2 Blocking 0'-7-1/2"	1-18'-0"
4'-3"	2	Studs Wall 4	Surplus 2-5'-3"	2-1'-0"	Scrap	None
3'-8-3/4"	49	Headers	Surplus 1-5'-8" 7-16'-0" 5-18'-0"	1-1'-11" 7-0'-11" 5-3'-0"	1-1'-9-1/2" 4-1'-9-1/2" 1-2'-1-3/4" 7-0'-11"	5-18'-0" 7-16'-0"
3'-1-1/4"	5	Studs Walls 2 & 4	Surplus 5-5'-8"	2'-6"	5-1'-9-1/2"	None
2'-1-3/4"	1	Studs Wall 4	Surplus 1-3'-0"	1-0'-8"	Scrap	None